Imaging at 7T Reveals New Septated Fine Structure in the Human Corpus Callosum

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Introduction:

The corpus callosum (CC) is a unique and heavily myelinated white matter structure that connects the left and right hemispheres in all vertebrate brains. It is well known from dissection, histological staining and diffusion MRI that the predominant fiber orientation is transverse. Studies of adult primate brain have so far revealed only gross distinctions along the anterior-posterior axis, between segments of the CC projecting to different cortical areas [1-3]. We have discovered a much finer modularity, a form of septation, using high resolution anatomical imaging and DTI**.**

Methods:

4 healthy subjects who gave informed consent were examined on a 7 Tesla whole body scanner (Siemens, Erlangen, Germany) with a 3D FLASH (TR/TE = 42/25ms**,** BW = 50Hz/px, 0.5 mm isotropic voxels) using a 24 element phased-array RF coil (Nova Medical Systems). DTI scans were performed on a Siemens 3T Tim Trio (Siemens, Erlangen, Germany) with gradient strength of 40 mT/m using a 32 channel phased-array RF coil, with a voxel resolution of 1.5 mm isotropic, 60 gradient directions, b= 1000s/mm^2 and a GRAPPA factor of 2. Diffusion tensors were then computed without further post-processing.

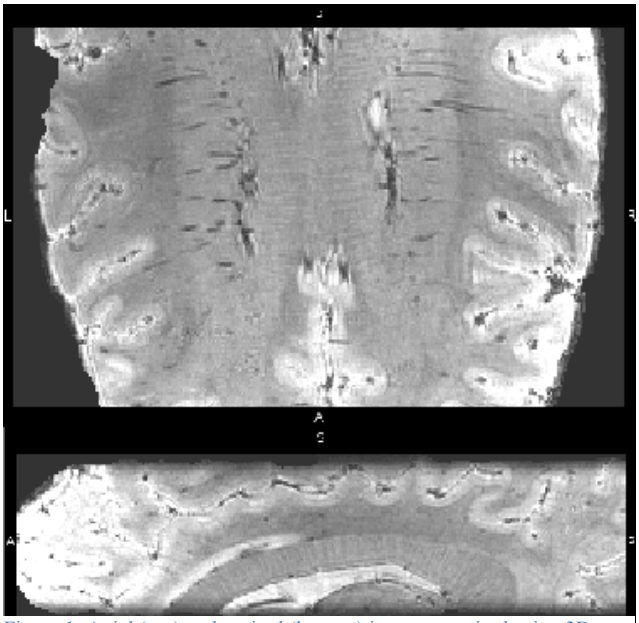

Figure 1: Axial (top) and sagittal (bottom) images acquired using 3D FLASH. Stripes can be seen across the callosal body.

Results:

The structural images reveal that the corpus callosum is not a homogeneous white matter body but has 'stripes' across it (Figure 1). In axial view (Figure 1, top) these stripes extend left to right along the axonal direction, whereas in the sagittal view they span the CC, running perpendicular to its dorsal and ventral surfaces (Figure1, bottom). No such stripes can be found in the coronal view (not shown). This is best explained as arising from quasi-two-dimensional planar structures forming septa that separate planes of axons passing transversely across the CC.

The DTI image of the same subject shows that the second eigenvector of the diffusion tensor in CC is consistently aligned dorso-ventrally (Figure 2). There is a strong bias for the water molecules to diffuse along these septa rather than across them. This bias is most likely to arise from tissue water within oriented structures other than the bundles of cylindrically symmetric axons that traverse the CC.

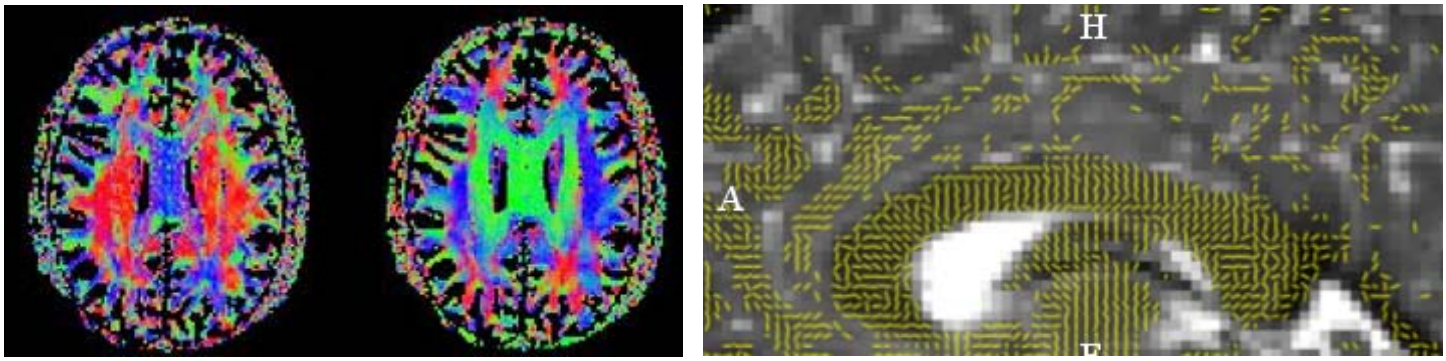

Figure 2: (a) Color-coded map of the 2nd (left) and 3rd (right) eigenvectors. Blue -> Dorsal-ventral, Green -> Anterior Posterior. (b) Sagittal view showing the 2nd eigenvector with direction overlaid on b0 image. The vectors run perpendicular to the superior and inferior surfaces of the corpus callosum.

Discussion and Conclusion:

These investigations *in vivo* with high resolution structural MRI show septated modular structure in adult CC that has previously gone unnoticed by more traditional techniques. Histological examination of fetal brain [4] shows similar structure. This structure is claimed to fade with later development, but histological studies of adult CC are absent from the literature. DTI confirms that a second preferred direction for water diffusion can be found that is consistent with this septation. Our data further suggest that water in compartments other than axonal fibers makes an important contribution to DTI data in this region of white matter. The implications for more detailed homologies of grey matter in each hemisphere remain to be explored.

References: [1] Pandya et al. *Brain Res*, 1971. **32**(1): p. 31. [2] Wakana et al. *Radiology*, 2004. **230**(1): p. 77. [3] de Lacoste et al. *J Neuropathol Exp Neurol*, 1985. **44**(6): p. 578. [4] Jovanov-Milosevic et al. *Front Neuroanat*, 2009. **3**: p. 6.